Non-locality effects in the Eden growth model

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The Eden growth model [1], originally designed to study the growth of cell colonies, is a paradigmatic example of stochastic radial growth, in which the fluctuations in the interface are described by the celebrated Kardar-Parisi-Zhang (KPZ) universality class [2].

Recently, some experiments investigating the scaling behavior of the growth of colonies of different types of cells in agreement with the KPZ class have been reported [3, 4]. However, the evolution of cell aggregates is a nutrient-limited growth process that involves non-local fields while the KPZ equation, which introduced the KPZ universality class, is a strictly local model. In this work we propose a simple extension of the Eden model in order to take into account effects related to access to nutrients introducing non-locality in the growth rules in an Eden off-lattice model. This effect is included by adding an additional probability

$$P = 1 - \exp\left(-A_s \frac{\theta_s}{2\pi}\right) \qquad (1)$$

to accept the replication of a cell in the original Eden model rules. Here θ_s is the opening angle sought by the replicating cell and A_s the parameter controlling the intensity of this shadowing effect. The probability of creating a new particle should be related to the amount of space free from cells. A high/low value of A_s mimics a high/low density of nutrients. If A_s and, thus nutrient resources, is large the aggregate grows even if the angle θ_s is small. On the other hand, the aggregate needs very large θ_s to grow if A_s is small.

Figure 1 shows two aggregates for different values of this parameter. When the A_s increases, the aggregate resembles the original Eden clusters with a rough surface of circular shape. For high nutrient competition the non-locality effects brings forth and a finger-like shape is observed. We analyzed the scaling properties of the interfaces produced by the aggregates an characterized the regimes where KPZ scaling is observed.

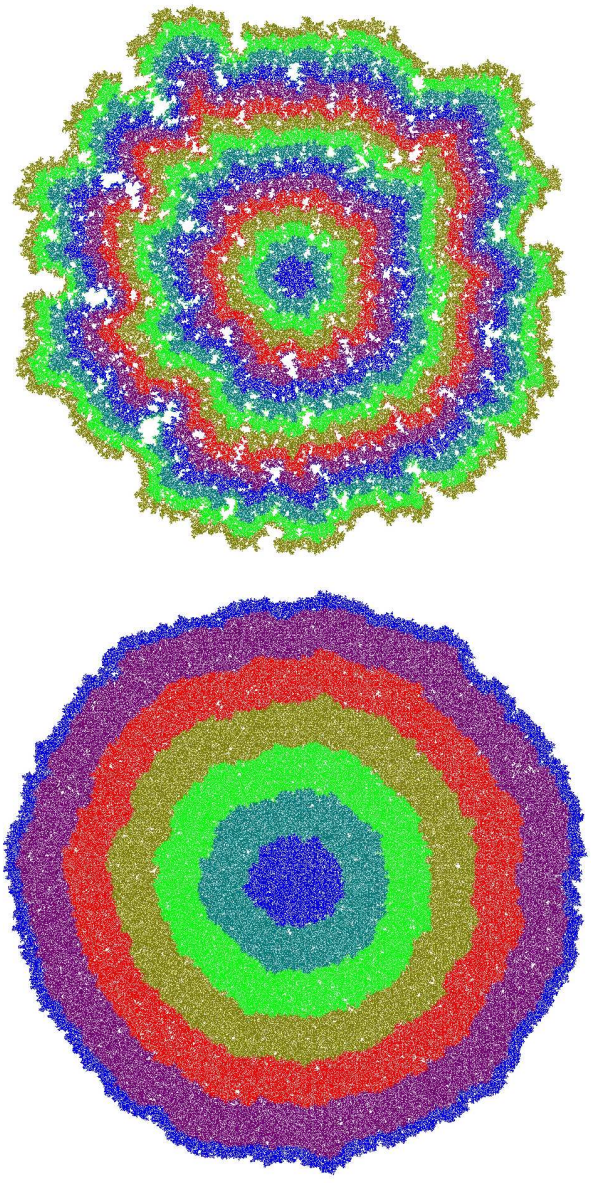

Figure 1: Aggregates for two different values of the parameter A_s according to equation (1). Top $A_s = 1$ and bottom $A_s = 9$. Colors changes every 150 steps.

[1] M. Eden. *A Two-dimensional Growth Process*. Proceedings of the Fourth Berkeley Symposium on Mathematical Statistics and Probability, **4**: Contributions to Biology and Problems of Medicine, 223–239, University of California Press, Berkeley, Calif., (1961).

[2] M. Kardar, G. Parisi and Y.-C. Zhang. *Dynamic Scaling of Growing Interfaces*. Physical Review Letters, **56**, 889, (1985).

[3] M.A.C. Huergo, M.A. Pasquale, P.H. González, A.E. Bolzán and A.J. Arvia. *Growth dynamics of cancer cell colonies and their comparison with noncancerous cells*. Physical Review E, **85**, 011918 (2012).

[4] M.A.C. Huergo, M. A Pasquale, P.H. González, A.E. Bolzán, and A.J. Arvia, *Dynamics and morphology characteristics of cell colonies with radially spreading growth fronts*, Physical Review E, **84**,021917 (2011).